



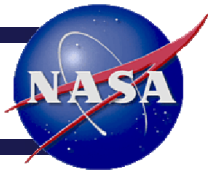
GSFC • 2015

An Upgrade of the Imaging for Hypersonic Experimental Aeroheating Testing (IHEAT) Software

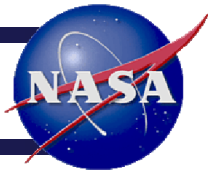
Michelle L. Mason, Shann J. Rufer
NASA Langley Research Center



Presentation Outline



Topic	Slides
• Introduction	3
• Experimental Facilities	4, 5
• Phosphor Thermography Overview	6-8
• New Software Features	9
– Piecewise versus Length Tool	10
– Batch Processing	11
– Global Uncertainty Data	12
– Mapping Global Data to 3D Model	13, 14
• Validation - comparison to IHEAT 3.2	15-17
• Conclusions	18
• Future Work	19



The purpose of this presentation is to demonstrate the capabilities of the Imaging for Hypersonic Experimental Aeroheating Testing code, version 4.0.

Goals of Software Upgrade

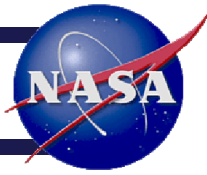
- Capture all of the capability of the legacy code in a MATLAB version of IHEAT
- Improve the techniques used to extract data from regions of interest
- Correlate the global heat transfer pattern in a 2D image to a 3D CAD model
- Increase efficiency of the phosphor thermography data reduction process

Code Impact

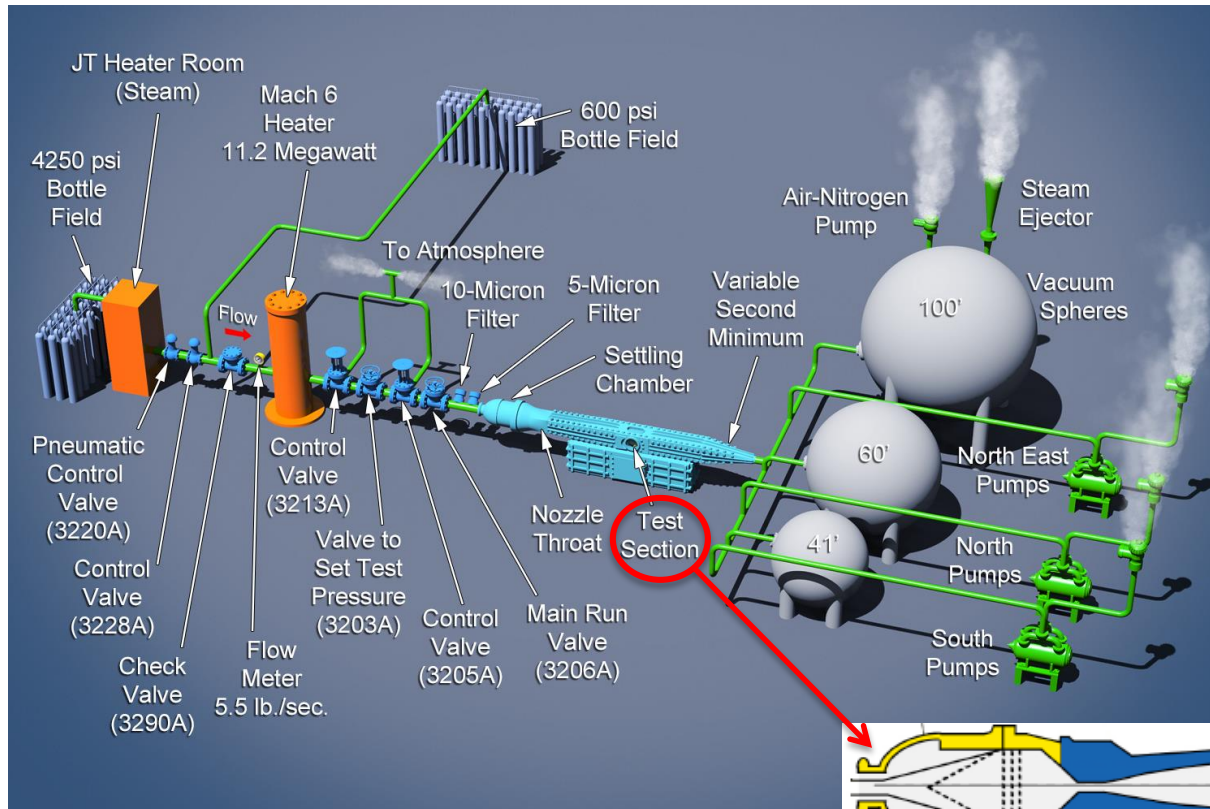
- IHEAT is the primary method to reduce LAL phosphor thermography data
- New tools simplify the data reduction process and reduce the time required to analyze the phosphor thermography data
- A stand-alone executable file compiled in MATLAB minimizes the effects due to changes in the language over time, making the software more reliable



Experimental Facility

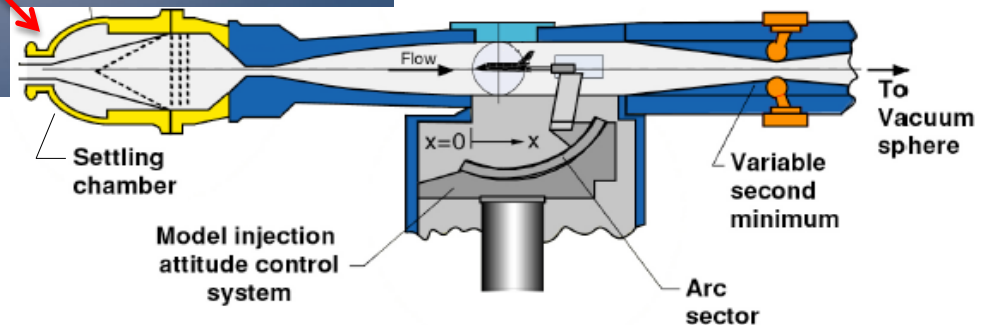


Langley Aerothermodynamics Laboratory 20-Inch Mach 6 Air Tunnel



Nominal Tunnel Conditions:

- Mach 6
- $Re: 0.5-8.3 \times 10^6/ft$
- $T_{t,1}: 805-935 \text{ }^\circ R$
- $P_{t,1}: 30-480 \text{ psia}$
- Test section: 20.5" x 20.0" with 12"x12" core flow
- Run duration: Up to 15 minutes
- Test gas: Dry air

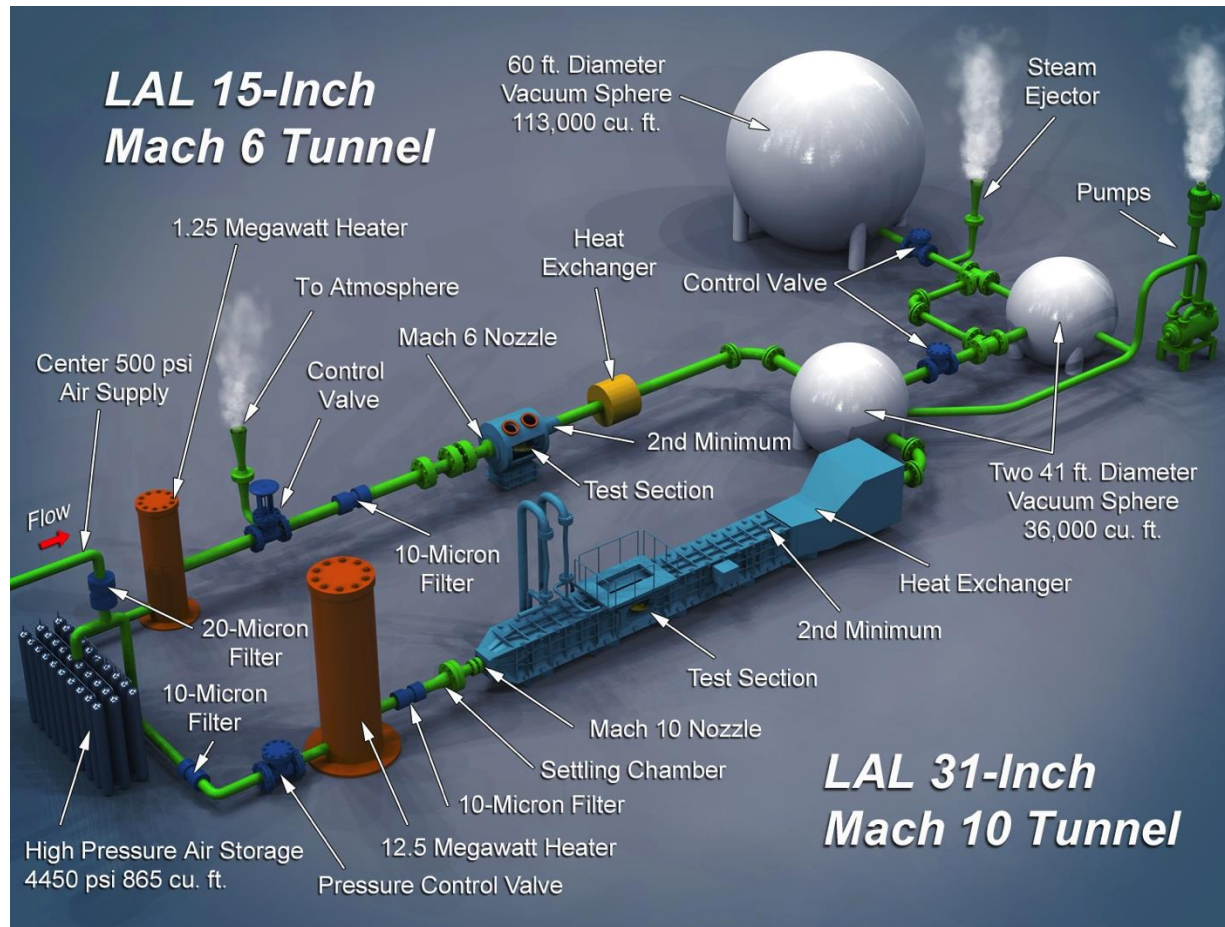




Experimental Facilities



Langley Aerothermodynamics Laboratory Air Tunnels



Nominal Tunnel Conditions:

31-inch, Mach 10:

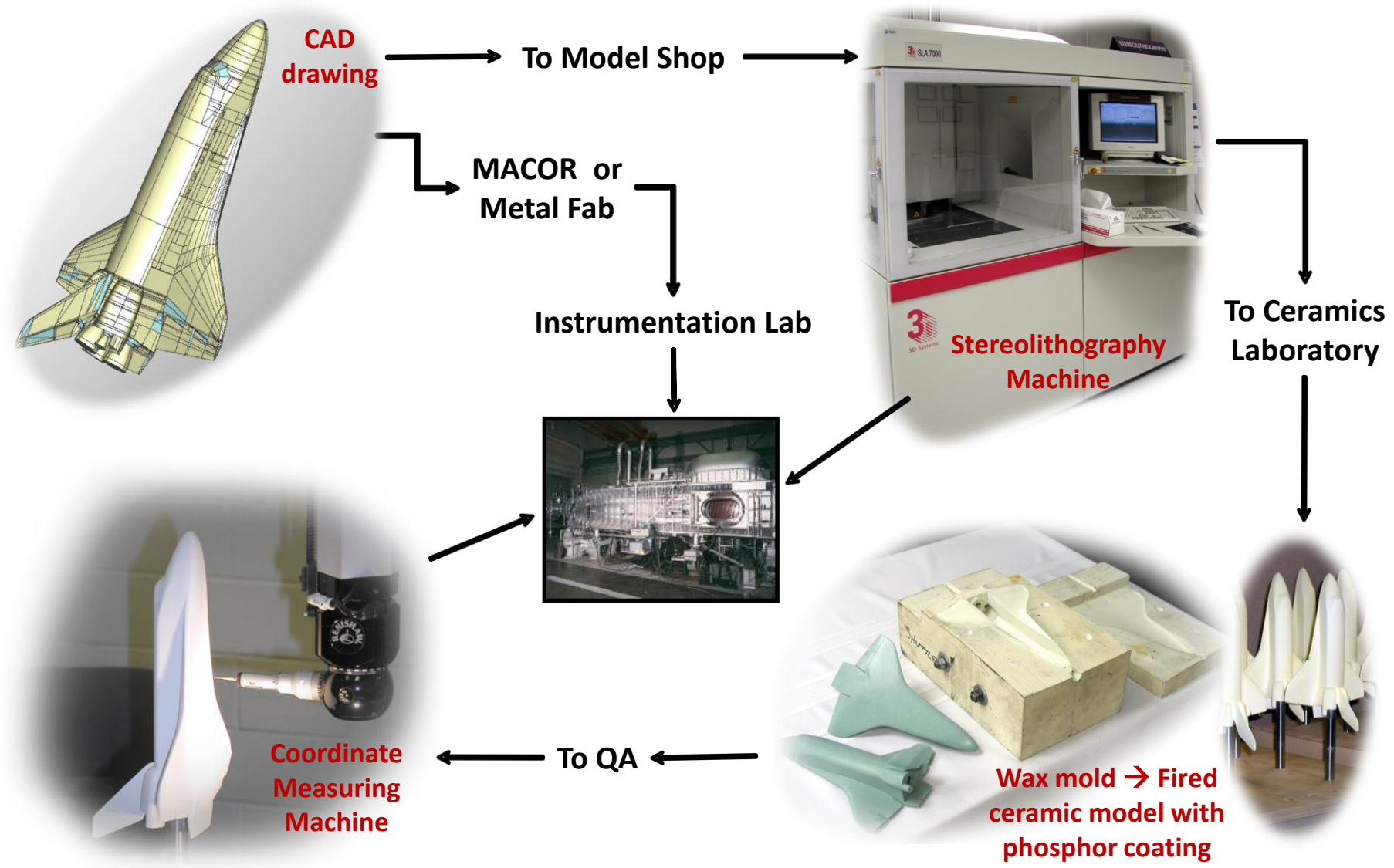
- $Re: 0.5-2.0 \times 10^6/ft$
- $T_{t,1}: 1775-1790^\circ R$
- $P_{t,1}: 350-1450 \text{ psi}$
- Test section: 31" x 31"
- Max run duration: 2 minutes
- Test gas: Dry air

15-inch, Mach 6:

- $Re: 1.3-7.0 \times 10^6/ft$
- $T_{t,1}: 870-1210^\circ R$
- $P_{t,1}: 100-400 \text{ psi}$
- Test section: 15"-diameter nozzle exit, open jet facility
- Max run duration: 2 minutes
- Test gas: Dry air

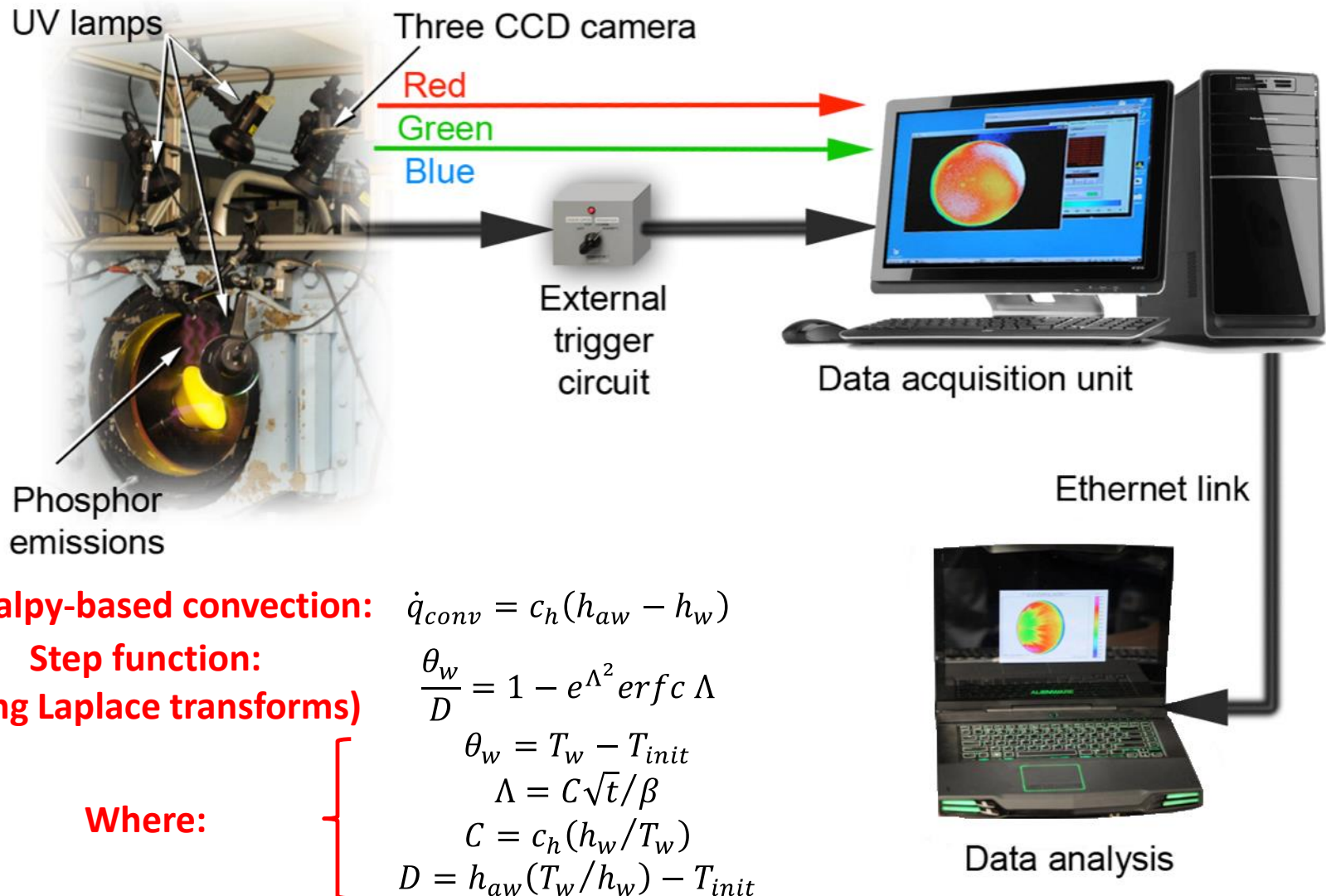
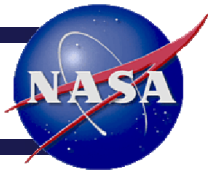


Model Fabrication Process



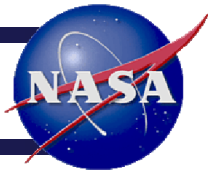


Phosphor Thermography



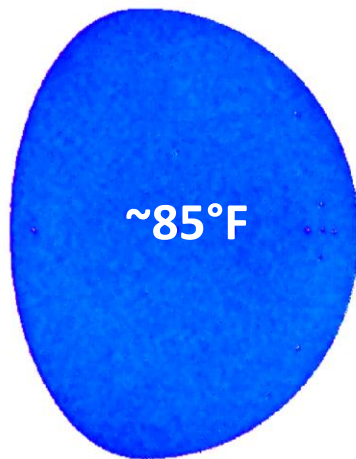


IHEAT Code Assumptions:

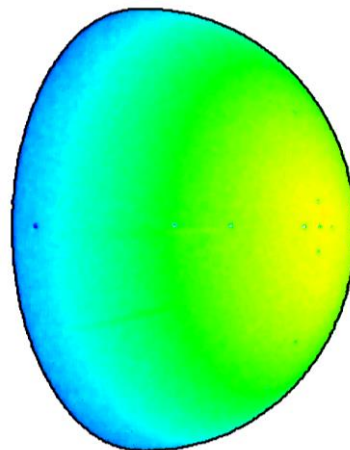


- One-dimensional (1D), semi-infinite conduction is assumed
- Convection boundary condition (BC)
- Step function in heating as model passes through the tunnel boundary layer before it reaches the wind tunnel centerline
- Stagnation-point Fay-Riddell heat transfer is used as the reference value to compute non-dimensional data

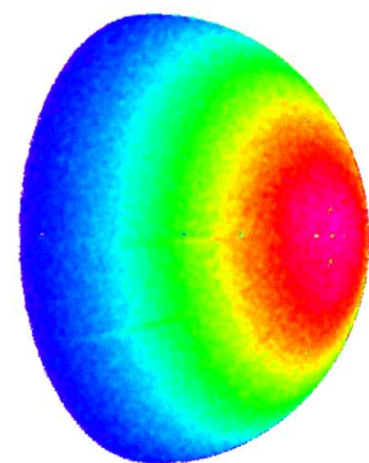
Pre-run Temperature



Run Temperature



Heat Transfer



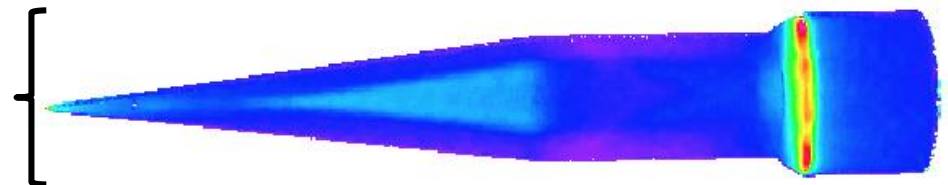


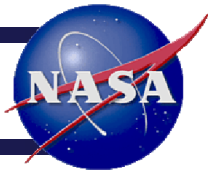
New Tools in IHEAT 4.0



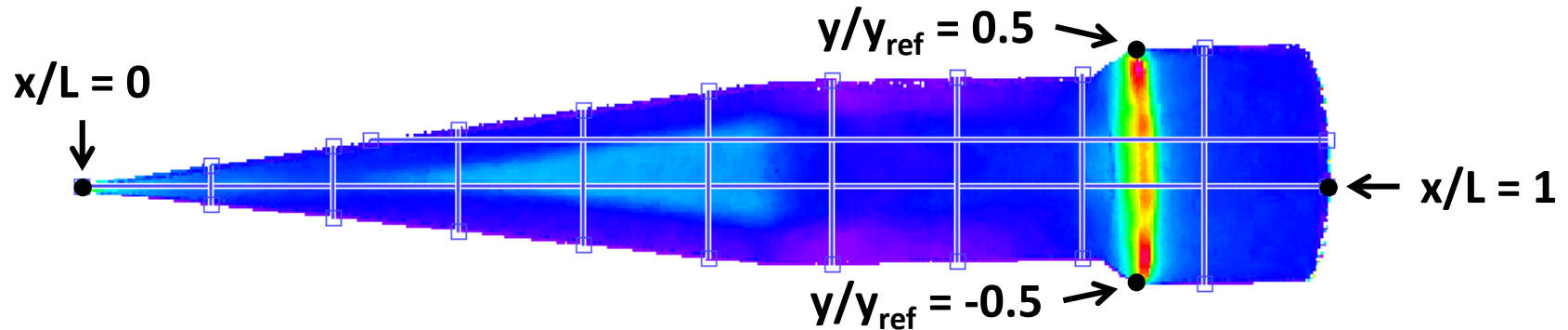
- Load Run – automatically load all input files for a run
- Comprehensive Data button – see all available data at each pixel on the model
- Activate Line Cuts – exactly replicate line cut locations
- Pre-run Temperature Check – indicates whether pre-run temperatures are reasonable
- Piecewise Line Cut
- Batch and Temporal Collapse Figure
- Run Temperature Uncertainty Image
- 3D Mapping to CAD model

Examples of the tools listed in red will be shown using HIFiRE1 Data





Auto Profile Grid of Line Cuts on HIFiRE-1 Model



- Temporal collapse of data for the run is computed automatically
- Batch process speeds up heat transfer analysis – data reduction times of hours are reduced to minutes for runs in which every frame of 30 Hz data is recorded
- IHEAT 4.0 is run remotely on a separate server, so a user can complete other tasks and a Batch process simultaneously without reducing available memory on the host system

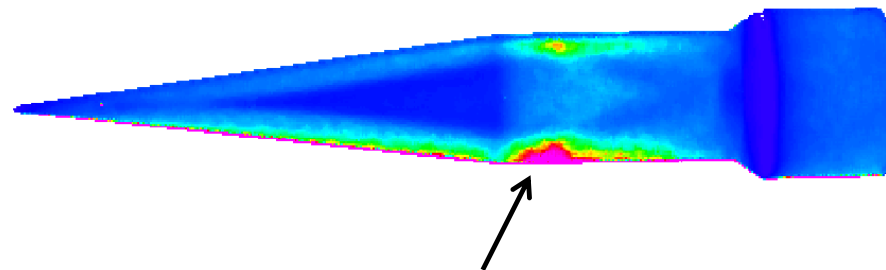


Uncertainty Image



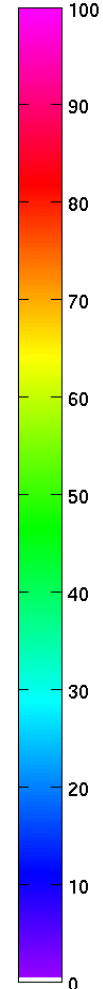
FRESH FX Test Run Uncertainty Mapping, Test 6928, Run 37
 $M_\infty = 6.03$, $\alpha = 0^\circ$, $Re_\infty = 5.62 \times 10^6/\text{ft}$

Total uncertainty at each pixel = uncertainties in heat transfer values due to wind tunnel conditions, the model's thermal properties, and the temperature difference between the pre-run and run temperatures.



Higher uncertainty values near the edge of the model and where ΔT is smaller

Run Uncertainty, %



NASA Langley Research Center

Aerothermodynamics Branch

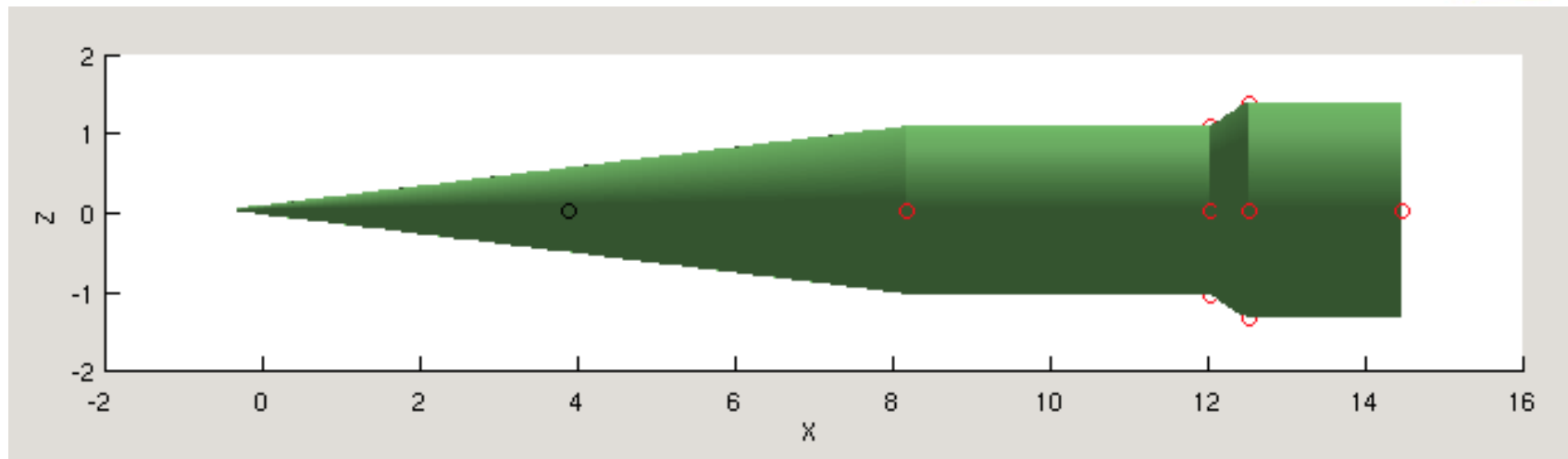
Preliminary Data



Map 2D Global Data to a 3D CAD model



- User provides fiducial mark correlations between 2D locations on image and 3D (x, y, z) coordinates on model
- User specifies the approximate location of the camera relative to the CAD model to yield a view similar to the 2D image
- User selects the appropriate focal length (from a range of plausible options) to map the image to the CAD model
- User can map the pre-run or run temperature, heat transfer or uncertainty data to the 3D CAD model





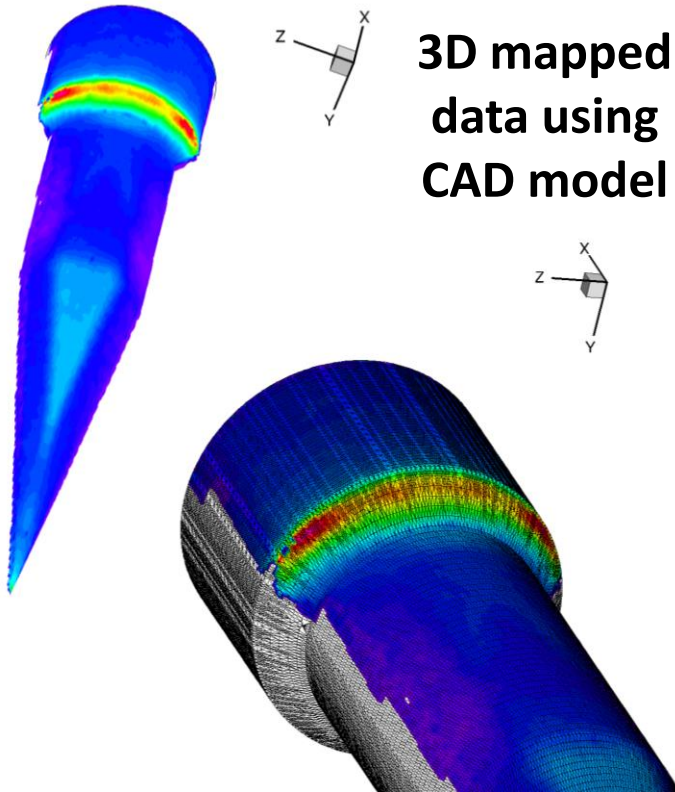
3D Mapped Output in Tecplot



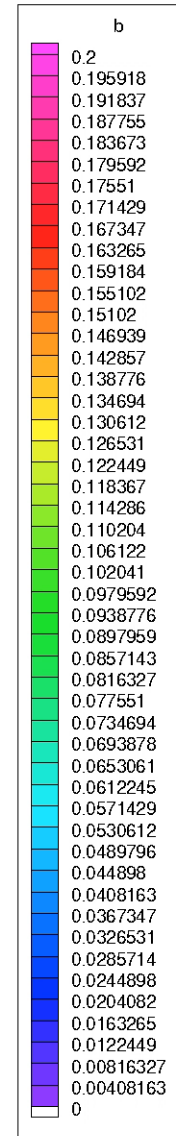
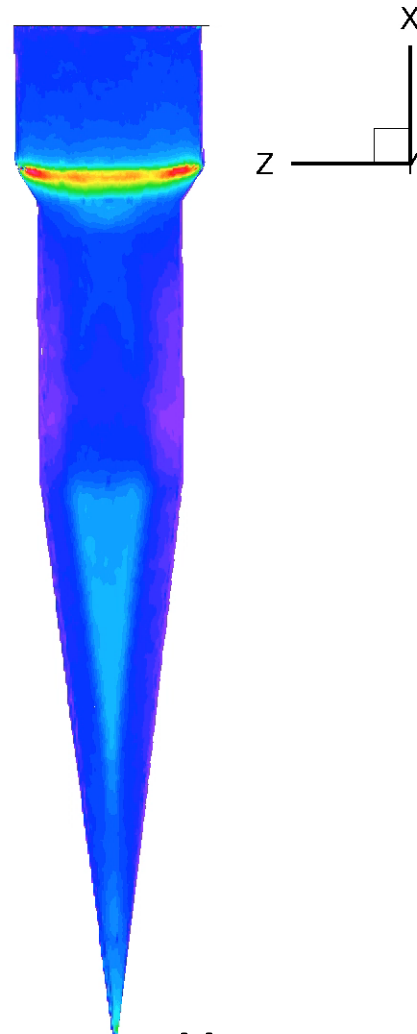
2D global heat transfer image
from IHEAT 4.0 (in MATLAB)



3D mapped
data using
CAD model



3D mapped heat transfer data,
rotated about z-axis (in Tecplot)

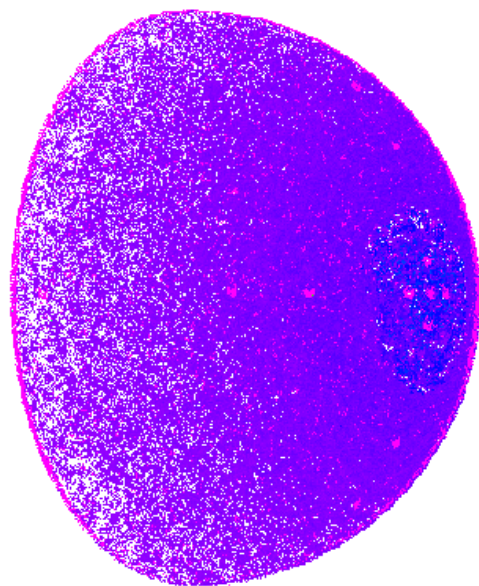




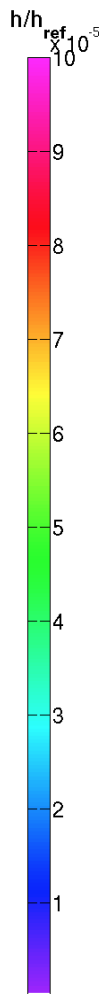
Absolute Difference – IHEAT 4.0 to IHEAT 3.2



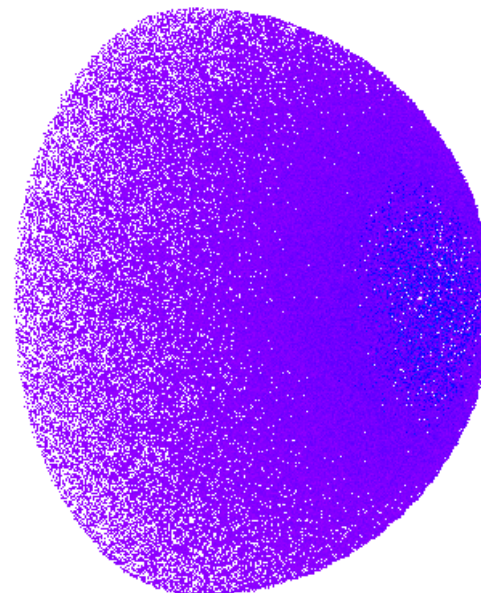
Median and Sobel Filtered Data Hemisphere Calibration Run



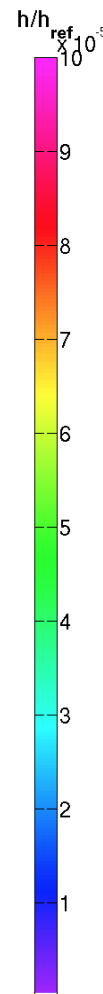
$h/h_{\text{ref}}, 0 \text{ to } 10 \times 10^{-5}$



Unfiltered Data Hemisphere Calibration Run

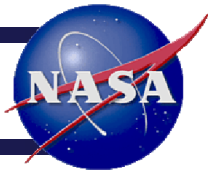


$h/h_{\text{ref}}, 0 \text{ to } 10 \times 10^{-5}$

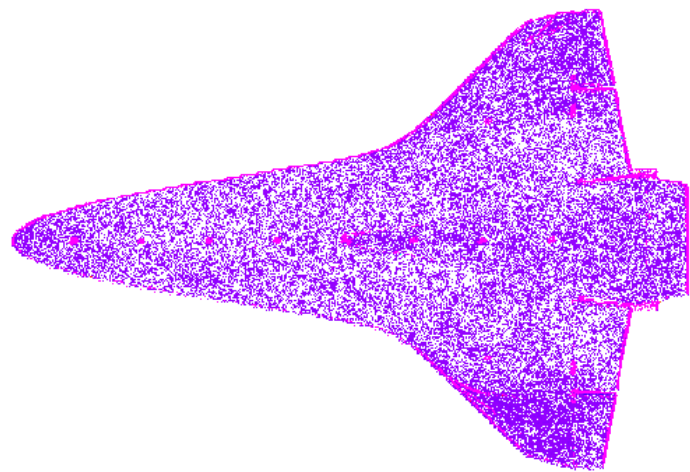




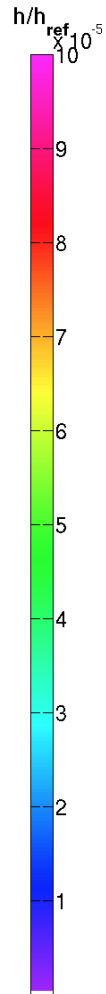
Absolute Difference – IHEAT 4.0 to IHEAT 3.2



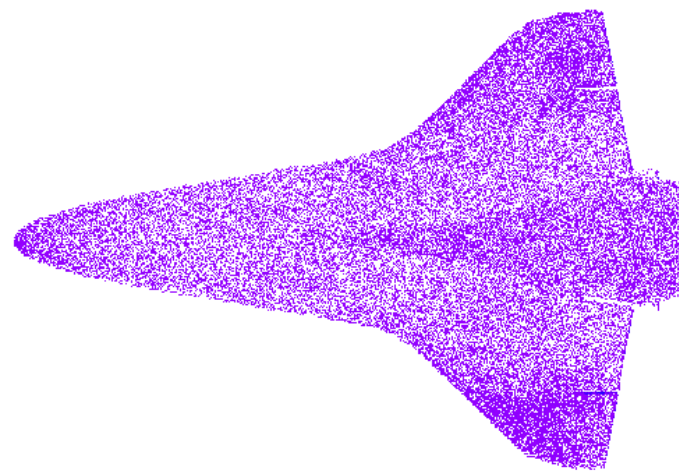
**Median and Sobel Filtered Data
Space Shuttle Run**



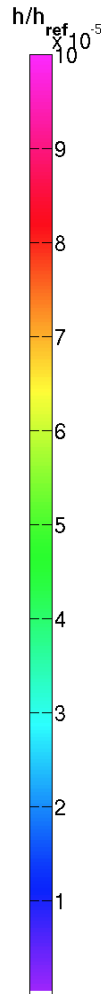
h/h_{ref} , 0 to 10×10^{-5}



**Unfiltered Data
Space Shuttle Run**



h/h_{ref} , 0 to 10×10^{-5}

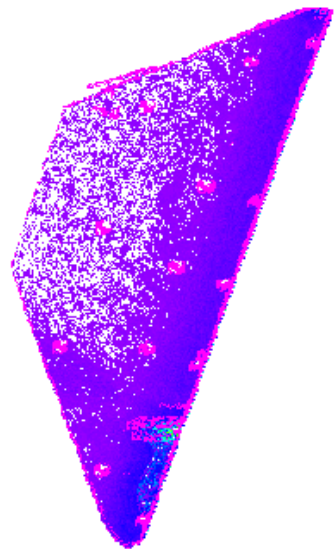




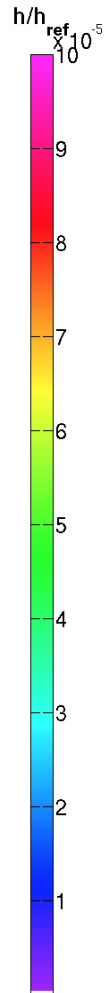
Absolute Difference – IHEAT 4.0 to IHEAT 3.2



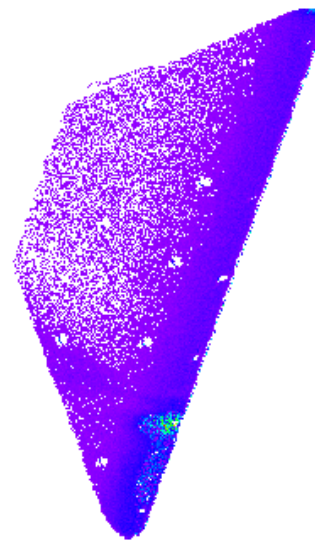
Median and Sobel Filtered Data Shock-Shock Interaction Run



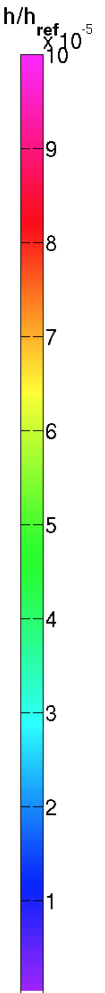
$h/h_{\text{ref}}, 0 \text{ to } 10 \times 10^{-5}$



Unfiltered Data Shock-Shock Interaction Run



$h/h_{\text{ref}}, 0 \text{ to } 10 \times 10^{-5}$



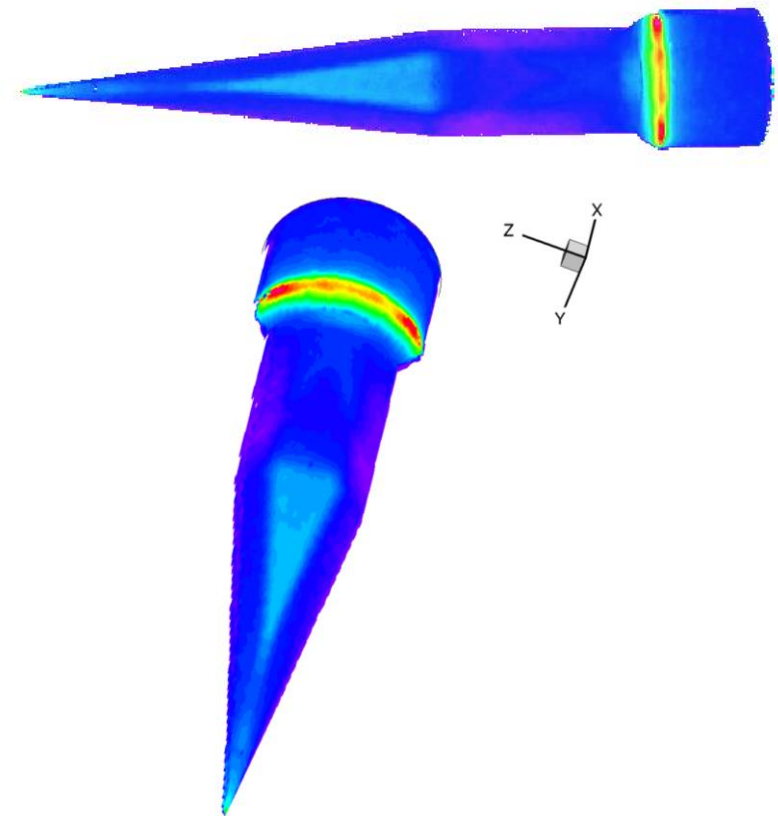


Conclusions



- IHEAT 4.0 allows the user to obtain data from segmented, “piecewise” line cuts along interesting features in the data.
- 2D global temperature and heat transfer information now can be mapped to 3D CAD models of the wind tunnel models as a Tecplot output from IHEAT 4.0.
- Through new tools such as Batch and Load Run, LAL phosphor thermography data can be analyzed more quickly and efficiently.
- Heat transfer calculations in the IHEAT 4.0 program have been validated through comparisons with IHEAT 3.2 output data.

Upgraded capability to reduce phosphor thermography data in NASA LAL wind tunnels





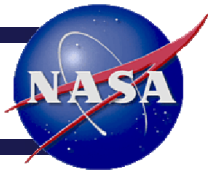
Future Work



- Improve the 3D mapping capability included in IHEAT 4.0
 - 2D and 3D heat transfer calculations should be incorporated into IHEAT 5.0+ to improve the accuracy of the mapped data
 - Modify 3D mapping code to load in binary CAD files to reduce the processing time for the 3D mapping code
 - Reduce the number of user inputs describing camera orientation required to map data in 3D
 - Add the capability to easily extract line cut data from the 3D mapped output in Tecplot
- Incorporate algorithm to extrapolate ground test heat transfer coefficients to flight values
- Incorporate a higher temperature phosphor system (under development) to increase the maximum limit of LAL phosphor thermography temperature measurements to 300°C



Upgrade to IHEAT Software



Thank you! Questions?